MODELS OF THE THERMAL AND VOLCANIC EVOLUTION OF MARS. A. Weizman, D. Prialnik, and M. Podolak, Dept. of Geophysics and Planetary Sciences, Tel-Aviv University, Israel (ayelet@comet.tau.ac.il).

The surface of Mars shows many evidence of continued and diverse volcanic activity. The source for volcanism is partial melting in the mantle, as a result of two possible mechanisms: pressure release melting, when hot mantle rock ascends to fill gaps in the lithosphere, and plumes carrying hot material from the lower boundary layer to the upper boundary layer. Using numerical models, we calculate the rate of volcanism through time and compare the relative contributions of the two mechanisms.

Our basic thermal evolution model solves simultaneously the equations for energy conservation and hydrostatic equilibrium [1], uses two types of materials - silicates (olivine) and ferrous (Fe+FeS), with densities computed by the Murnaghan equation of state, and includes the phase transition olivine-spinel [2]. In the present model the energy equation is solved for the mantle as one zone, with an adiabatic temperature gradient. The mantle is separated from the lithosphere and core by thermal boundary layers, with thicknesses evaluated from the requirement that the Rayleigh number equals its critical value. For the upper boundary layer there is also the requirement of maximizing the Rayleigh number, and thus defining the limit between the mantle and the lithosphere [3].

The mantle material contains a low-melting-point material (basalt) that melts when it reaches the solidus. The process of partial melting depletes the mantle rock of incompatible elements, including the mantle heat sources, which migrate with the basalt to the lithosphere (so the mantle may be described as loosing fertility with time). Volcanism is defined as the (maximum) melt volume per unit area of the planet per unit time, while the contribution of core heat, delivered by plumes, is estimated by the fraction of material from the core-mantle boundary delivered to the upper boundary layer per unit time.

Fig. 1 shows volcanism rate (cm/yr) as a function of time, for a model with the radius and inertia factor of Mars (R = 3389 km and I = 0.366), and with composition corresponding to the core sulfur content of Xs = 14 wt%, as inferred from SNC meteorites [4]. The first two billion years are characterized by a high rate of volcanism decreasing fast by about 2 orders of magnitude (a).The solid line is an upper limit, since it includes all the melt produced in the upper mantle. If we take the estimation of [5], that the volume of igneous intrusions accompanying each eruption is at least ten times larger than the volume of volcanic material, the rate of mantle volcanism reduces to the short-dashed line. The long-dashed line is the contribution of plumes from the core-mantle boundary (assuming that 20% of the lower boundary layers material gets to the upper boundary layer), which becomes significant only when mantle volcanism decreases enough (b). The intersection time may vary by up to 1b.y. as a result of uncertainty in the viscosity parameters and in the data of radiogenic element concentrations .

The results suggest that Mars could be still volcanically active, and the origin of any recent volcanism was probably from plumes.

References: [1] Weizman et al. (1996) JGR, 101, 2235-2245. [2] Weizman et al. (1997) JGR, 102, 9205-9209. [3] Lunine and Stevenson (1985) Icarus, 64, 345. [4] Sohl and Spohn (1997) JGR, 102, 1613-1635. [5] Schubert et al.(1992) in MARS, 147-183.

Figure 1
Volcanism rate as a function of time